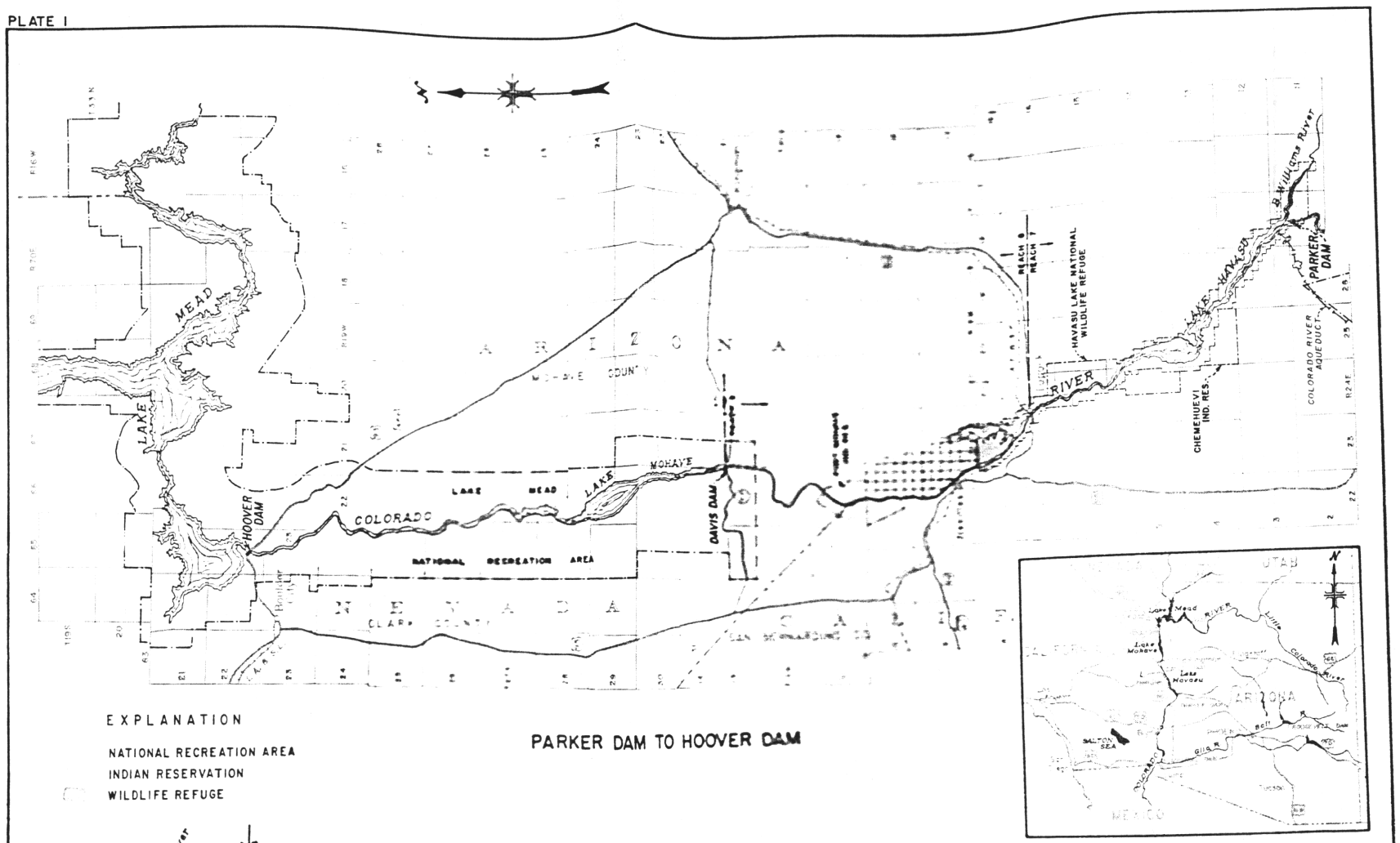
SECTION D

LOWER COLORADO RIVER PHREATOPHYTE ERADICATION AND CONTROL

PLATE I

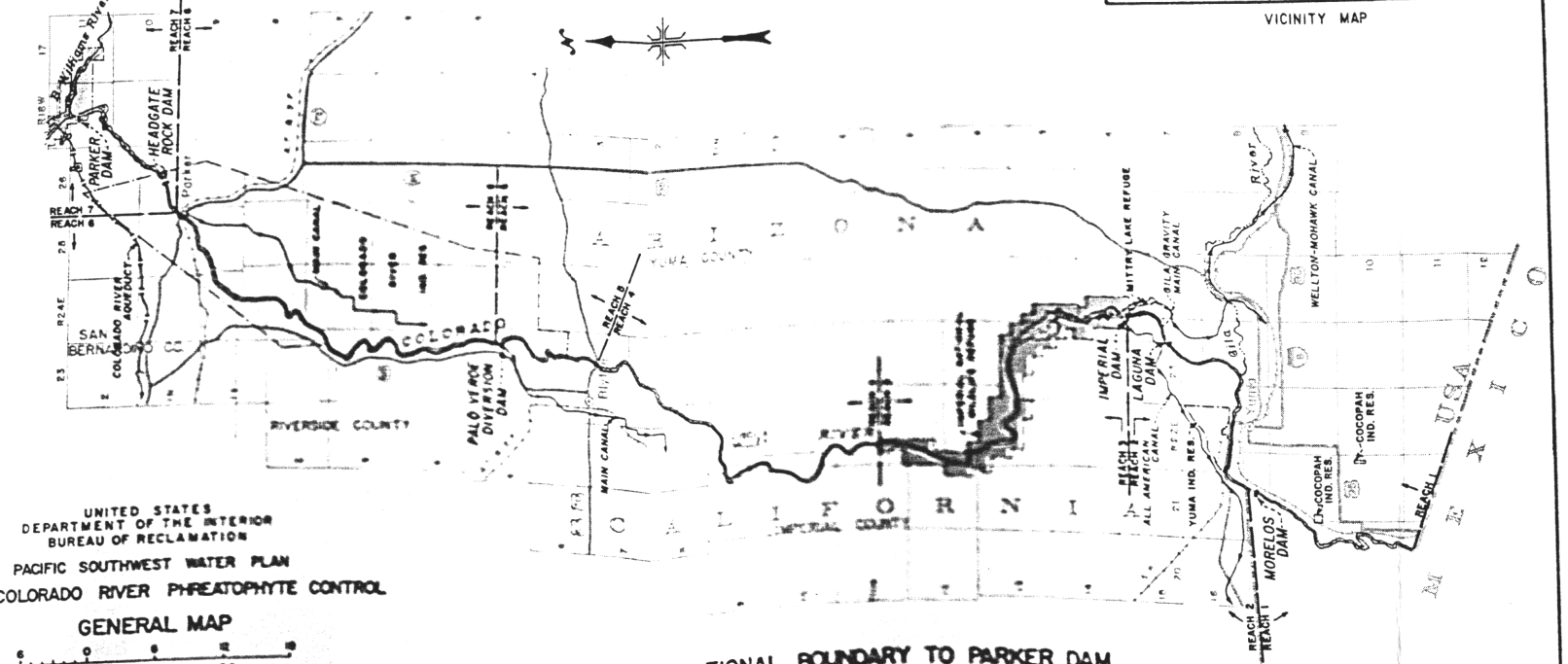


EXPLANATION

NATIONAL RECREATION AREA
INDIAN RESERVATION
WILDLIFE REFUGE

PARKER DAM TO HOOVER DAM

VICINITY MAP



INTERNATIONAL BOUNDARY TO PARKER DAM

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

LOWER COLORADO RIVER PHREATOPHYTE CONTROL

GENERAL MAP

6 0 6 12 18
SCALE OF MILES

OCTOBER 1963

Map No. 57-314-99

INTERIOR-RECLAMATION, BOULDER CITY, NEVADA

SECTION D - PHREATOPHYTE ERADICATION AND CONTROL

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FOREWORD

Steadily and relentlessly, high water-consuming plants, termed phreatophytes, containing species such as salt cedar, arrowweed, mesquite, and saltbush, have spread throughout the Lower Colorado River flood plain to where, in places, their growth is almost impenetrable. Each year over half a million acre-feet of Lower Colorado River water is nonbeneficially consumed by these prolific water-using shrubs and trees. A program for salvaging a portion of this water by the eradication and control of these plants is an integral part of the Pacific Southwest Water Plan.

Along with the increasing demands for additional water within the Pacific Southwest are the increasing demands for public use and recreation areas along the Lower Colorado River. It is anticipated that recreational developments now existing will increase and eventually spread over parts of lands in State, private, Federal, and Indian ownerships. Some portion of the recreation developments undoubtedly will be in the phreatophyte areas considered in this report.

It should be recognized that selective phreatophyte growth and managed vegetative land developments may be a desired use of the land and part of the water resources of the area. On areas noncritical to wildlife where the present phreatophyte growth has a low wildlife value, a program utilizing replacement vegetation of trees, shrubs, or grasses having a low water demand, could conserve additional water and produce greater wildlife values and recreational benefits.

Continued development of the flood plain lands is going to occur either on a planned basis or by random occurrence in the future, and could result in a net reduction of the present nonbeneficial consumptive water use and thereby accomplish some portion of water salvage.

Coordinated planning with public agencies along with the related private developments should provide the most effective and economical utilization of phreatophyte lands and optimum conservation of the waters now being nonbeneficially lost.

The study area, as shown on Plate 2, comprises about 294,000 acres, of which nearly 167,000 acres are presently invested with phreatophytes which annually consume about 568,000 acre-feet of water. About 22,000 acres of Federal lands and about 20,000 acres of nonarable Indian reservation lands are infested by phreatophytes with an annual nonbeneficial consumptive use of about 148,000 acre-feet of water. The proposed program of eradication and control of these phreatophytes

would annually salvage about 100,000 acre-feet of this amount for beneficial use by other areas within the Lower Colorado River Basin.

The clearing of phreatophytes from private, State-owned, and arable Indian reservation lands will be incidental to their continuing development and, therefore, is not included as a specific eradication program under the Pacific Southwest Water Plan.

The presentations in this report are supported by data contained in the Bureau of Reclamation's technical report, "Lower Colorado River Water Salvage Report--Phreatophyte Control, June 1963." The water salvage plans presented do not conflict with the proposed ground-water recovery plan or the authorized Lower Colorado River channelization plan.

The estimated costs associated with the phreatophyte eradication and control program would be $2,100,000 for clearing and $1,630,000 for the construction of surface drains. The total annual costs would be $341,000. The annual equivalent agriculture benefit based on a 100-year period of analysis is $3,200,000. The proposed eradication program is economically feasible, as the annual benefits would exceed annual costs by a ratio of 9.38 to 1.0.

SECTION D - PHREATOPHYTE ERADICATION AND CONTROL

PART I. THE AREA

General

The study area of this report, as shown on Plate 2, is the same as that used in the Bureau of Reclamation's "Lower Colorado River Water Salvage Report--Phreatophyte Control, June 1963," which presents supporting data for this report.

Location, Extent, and Features--The Lower Colorado River, between Davis Dam and the Arizona-Mexico boundary, alternately flows through 280 miles of narrow, rocky canyons and broad, alluvial-filled valleys. Throughout this reach, the Colorado River traverses two wildlife refuges, four Indian reservations, and five irrigation districts. Except for Federal lands in the Palo Verde Irrigation District, this study includes no lands in irrigation districts.

The study area encompasses private, State- and Federal-owned, Indian reservation, and Federal wildlife refuge lands. The approximate total areas by landownerships are as follows:

Type of Ownership	Area in Acres
Private	33,000
State	8,000
Federal	48,000
Indian	140,000
Wildlife refuge (Federal)	34,000
Open water	31,000
Total	294,000

Population--The vast region along the Lower Colorado River is very sparsely settled. Yuma, Arizona, with a population of about 24,000, was the largest of five cities enumerated by the U.S. Census Bureau in 1960. The remaining four cities had a combined population of about 14,000. Lesser numbers of people are dispersed in irrigation and recreation developments.

Land Uses

Agricultural Development--About 207,000 acres of river bottom land are irrigated, of which approximately 147,000 acres are in irrigation-water service organizations not included in the phreatophyte study area. As presented in Table 1, of the 60,000 acres of irrigated lands in the study area, about 34,700 acres are Colorado River Indian Reservation lands.

EXPLANATION

- Study Area Boundary
- Generalized Colorado River Flood Plain Boundary
- Spoil Area For Tentative Future Settling Basin
- Tentative Floodway For Future Channelization

	Salt Cedar	Sb	Salt Bush
	Arrow Weed	B	Baccharis
	Tules	W	Willow
Mx	Mixed	Cc	Carrizo Cane

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

LOWER COLORADO RIVER PHREATOPHYTE CONTROL

PHREATOPHYTE INFESTED AREAS

Map No. 57-314-100

Based on conditions in Spring 1962

1 0 1 2 3 4
SCALE OF MILES

SHEET 1 OF 5 SHEETS

INTERIOR-RECLAMATION, BOULDER CITY, NEVADA

ARIZONA

CALIFORNIA

Morch line sheet 3

Morch line sheet 1

Reach No. 4

Reach No. 3

IMPERIAL WILDLIFE REFUGE BOUNDARY

UNSURVEYED

UNSURVEYED STRIP

IMPERIAL WILDLIFE REFUGE

Lake Mohave

Lake Havasu

Topock Marsh

Mohave Ruins

Fergusons Lake

EXPLANATION

- Study Area Boundary
- Generalized Colorado River Flood Plain Boundary
- Proposed Channelization Alignment
- Proposed Levee
- Salt Cedar
- Arrow Weed
- Tules

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

LOWER COLORADO RIVER PHREATOPHYTE CONTROL

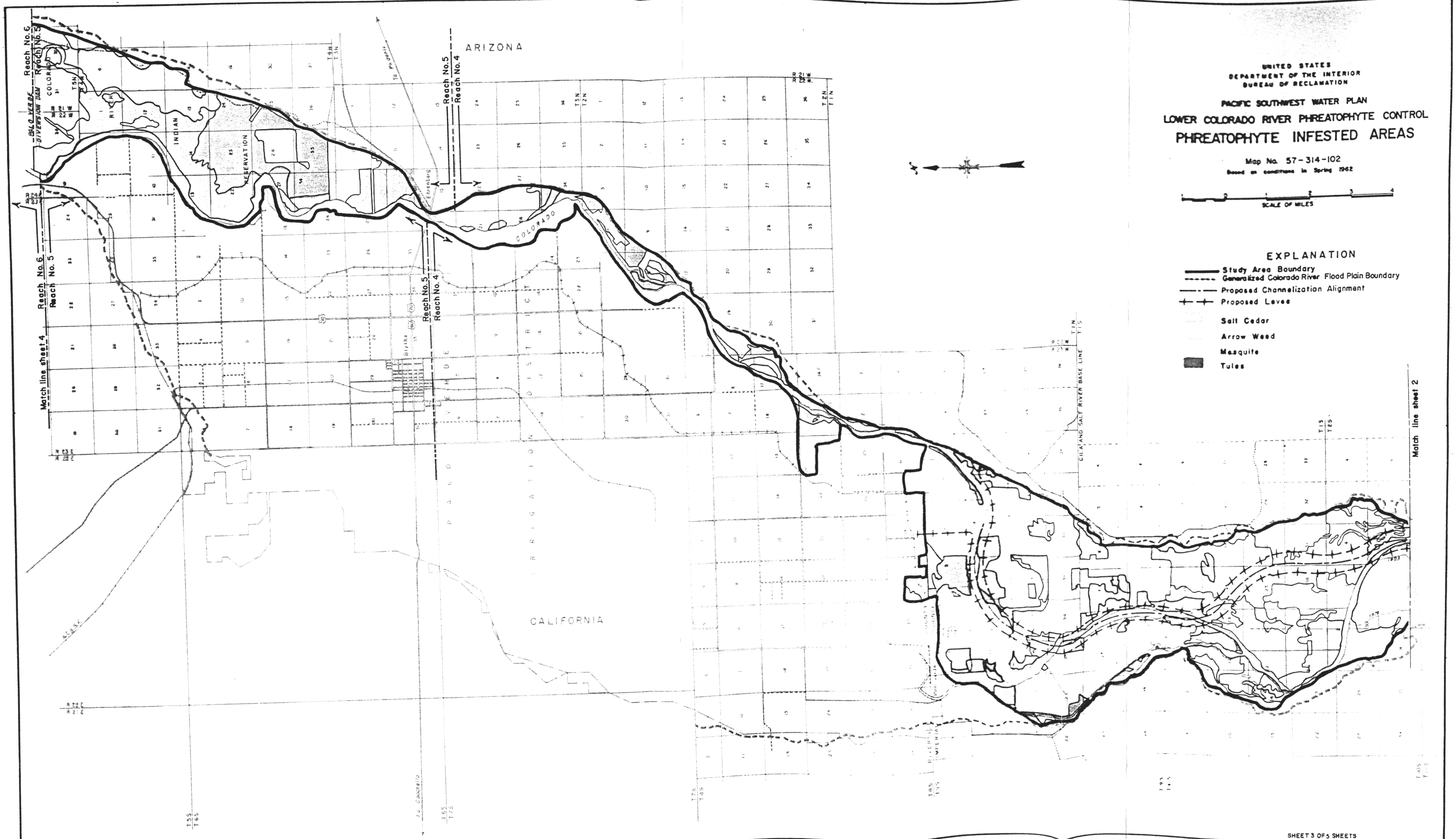
PHREATOPHYTE INFESTED AREAS

Map No. 57-314-101

Based on conditions in Spring 1962

SCALE OF MILES

INTERIOR-RECLAMATION, BOULDER CITY, NEVADA



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

LOWER COLORADO RIVER PHREATOPHYTE CONTROL

PHREATOPHYTE INFESTED AREAS

Map No. 57-314-102
Based on conditions in Spring 1962

SCALE OF MILES

EXPLANATION

- Study Area Boundary
- Generalized Colorado River Flood Plain Boundary
- Proposed Channelization Alignment
- Proposed Levee
- Salt Cedar
- Arrow Weed
- Mesquite
- Tules

INTERIOR-RECLAMATION, BOULDER CITY, NEVADA

NO PHREATOPHYTE STUDIES FOR REACH 7

to Wickenburg

Reach No. 7

Reach No. 6

Parker Town site

COLORADO RIVER INDIAN RESERVATION BOUNDRY

EXPLANATION

- Study Area Boundary
- Generalized Colorado River Flood Plain Boundary
- Tentative Future Channelization Alignment
- Tentative Floodway For Future Channelization

	Salt Cedar	Sb	Salt Bush
	Arrow Weed	B	Baccharis
	Mesquite	W	Willow
	Tules	Cc	Carrizo Cone
Mx	Mixed		

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

LOWER COLORADO RIVER PHREATOPHYTE CONTROL

PHREATOPHYTE INFESTED AREAS

Map No. 57-314-103

Based on conditions in Spring 1962

1 0 1 2 3 4

SCALE OF MILES

Reach No. 6

Match line sheet 3 & Reach No. 5

Reach No. 6

Match line sheet 3 & Reach No. 5

SHEET 4 OF 5 SHEETS

INTERIOR-RECLAMATION, BOULDER CITY, NEVADA

ARIZONA

DAVIS DAM 1 MILE (NORTH LIMIT REACH NO.8)

Davis Dam (Civil Town)

Bullhead City

LAKE MEAD NATIONAL RECREATION

Reach No.8

Reach No.7

NOTE: NO PHREATOPHYTE STUDY - HAVASU NAT'L. WILDLIFE REFUGE - IN REACH NO. 7

NEVADA

CALIFORNIA

California-Nevada state boundary as U.S.C.& G.S. surveyed 1893 to 1893.

California-Nevada state boundary surveyed in 1873 by Van Schmidt.

EXPLANATION

Study Area Boundary

Generalized Colorado River Flood Plain Boundary

	Salt Cedar
	Arrow Weed
	Mesquite
	Tules
Mx	Mixed
Sb	Salt Bush
B	Baccharis
W	Willow
Cc	Carrizo Cane

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PACIFIC SOUTHWEST WATER PLAN

LOWER COLORADO RIVER PHREATOPHYTE CONTROL

PHREATOPHYTE INFESTED AREAS

Map No. 57-314-104

Based on conditions in Spring 1962

SCALE OF MILES

SHEET 5 OF 5 SHEETS

INTERIOR-RECLAMATION, BOULDER CITY, NEVADA

Table 1

ACREAGE OF IRRIGATED AND NONIRRIGATED LANDS BY OWNERSHIP AND RIVER REACH

REACH NO.	ARABLE LANDS										NONARABLE LANDS 2/										GRAND TOTALS	
	PRIVATE		STATE		FEDERAL 1/		INDIAN		TOTAL		PRIVATE		STATE		FEDERAL 1/		INDIAN		TOTAL			
	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.
1	780	70	570	0	1,310	1,240	0	0	2,660	1,310	50	800	20	30	50	1,250	0	0	120	2,080	2,780	3,390
2	490	250	80	160	3,840	3,230	0	0	4,410	3,640	10	1,470	30	940	190	6,320	0	0	230	8,730	4,640	12,370
3 3/	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1,750	1,590	580	440	5,890 4/	6,500	0	0	8,220	8,530	2,690	4,160	390	590	1,200	8,670	0	0	4,280	13,420	12,500	21,950
5 4/	780	280	0	0	0	140	0	8,280	780	8,700	0	210	0	10	0	140	0	1,490	0	1,850	780	10,550
6 5/	70	60	0	0	1,320	890	34,710	66,570	36,100	67,520	0	100	0	0	250	1,480	0	2,440	250	4,020	36,350	71,540
7	0	10	0	0	40	0	0	30	40	40	0	160	0	0	0	670	0	500	0	1,330	40	1,370
8	2,570	3,730	0	710	100	340	0	8,290	2,670	13,070	380	10,530	0	2,980	0	3,100	0	18,140	380	34,750	3,050	47,820
Totals	6,440	5,990	1,230	1,310	12,500	12,340	34,710	83,170	54,880	102,810	3,130	17,430	440	4,550	1,690	21,630	0	22,570	5,260	66,180	60,140	168,990

1/ Does not include wildlife refuges. These lands not inventoried.

2/ Includes 37,460 acres (6,540 irrigated and 30,920 nonirrigated) temporarily placed in land class 5d, pending further studies.

3/ Not inventoried--Imperial Wildlife Refuge.

4/ Includes 2,760 acres of Federal land in Palo Verde Irrigation District.

5/ Lands within Colorado River Indian Reservation situated on Arizona side of river not inventoried for this study--Land classification data obtained from Bureau of Indian Affairs.

Undeveloped Lands--There are approximately 169,000 acres of undeveloped lands in the study area, of which about 103,000 acres are arable. About 79,000 acres of the undeveloped lands are within the Colorado River Indian Reservation, of which approximately 75,000 acres have been classified as arable by the Bureau of Indian Affairs.

Fish and Wildlife Refuges--Between Davis Dam and the International Boundary, the Colorado River traverses two wildlife refuges, as shown on Plate 1. The Havasu National Wildlife Refuge extends about 50 miles, from eight miles above Topock, Arizona, downstream to the vicinity of Parker Dam. The Imperial Wildlife Refuge extends about 30 miles downstream from the southern end of Cibola Valley to Imperial Dam.

The only portion of the Havasu National Refuge included in the vegetative survey is about 14,000 acres lying within the flood plain from the upper end of the refuge down to Topock. About 20,000 acres of the Imperial Wildlife Refuge are within the Colorado River flood plain and study area. Within the lower portion of this refuge are numerous sloughs, lakes, and large areas of tules. In the upper portion, the river is bordered on both sides with long, narrow growths of vegetation, predominantly salt cedar and arrowweed.

Resorts--Attracted by the mild, almost rain-free winter, the Lower Colorado River is a popular recreation area for people from the metropolitan areas of San Diego, Los Angeles, Las Vegas, and Phoenix, as well as those from Yuma, Blythe, Parker, and Needles. A considerable number of outdoor enthusiasts also visit the area during the hot summer months. There are numerous facilities for these visitors and seasonal residents that range from small fishing camps to rather elaborate resorts. There are facilities on Lake Havasu, along both sides of the river from Parker Dam to Palo Verde Diversion Dam, and in the vicinity of Imperial Dam and Reservoir. Of these, the most extensive and highly developed resort area lies between Parker and Headgate Rock Dams.

The increasing demand for recreation facilities and services throughout the valley is spurring various State, county, and local agencies to develop plans for additional recreation and park areas from Davis Dam to the International Boundary. These plans will be presented in a land-use report for the Lower Colorado River being prepared by the Lower Colorado River Land Use Office at Yuma, Arizona.

Vegetation

The vegetation of the flood plain study area, from Davis Dam to the International Boundary, consists predominantly of salt cedar, arrowweed, and mesquite. There are also numerous less extensive growths of cottonwood, willow, saltbush and baccharis. Extensive growths of tules and smaller areas of carrizo cane are found in the shallow waters and low-lying lands of the swamps, sloughs, back bays, and seeped areas, the major portion of which are located on the

wildlife refuges. Most of the mesquite and nearly half of the arrowweed growing in the study area are located within the Colorado River Indian Reservation. Of the total acreage of salt cedar, nearly half is found in the reach from Topock to Davis Dam. The remaining plant species on the flood plain are in scattered growths throughout the various river reaches.

Water Uses

Surface Water--Colorado River water is diverted at various locations along the river below Davis Dam for irrigation, municipal, and industrial uses in the lower basin and in Mexico. In addition, and outside of water service organizations, private operators are irrigating about 21,000 acres along both sides of the river by either pumping directly from the river or from ground-water wells adjacent to the river.

Ground Water--Ground waters underlie all the lands adjacent to the Colorado River in both Arizona and California. Irrigation developments draw upon this supply to supplement surface-water diversions; however, the amount of ground water used in these areas is insignificant. Ground water is the entire source of municipal and industrial supply for the cities of Needles, Blythe, and Parker.

Subsurface Water--Subsurface water, that portion of ground water which flows near the surface, is the primary source of water used by phreatophytes, as these plants habitually obtain their supplies from the zone of saturation. Phreatophytes are the major users of subsurface water in the study area.

PART II. FIELD INVESTIGATIONS

The study area 1/ was divided into eight river reaches for conducting the various field surveys and presenting the results of the investigations. Aerial photographs were used for the phreatophyte and land inventories.

The study area boundary, for the most part, followed the generalized flood plain boundary but did not include lands in existing irrigation districts, with the exception of those federally owned lands within the Palo Verde Irrigation District. The study area and the river reach boundaries are shown on Plate 2.

The estimated use of water by phreatophytes presented in this report was based on a field vegetative survey, together with Blaney-Criddle water-use factors, rather than the water inventory method. The many flow measurements, all subject to small error, plus the

1/ As presented in the Bureau's Report on the Lower Colorado River Water Salvage - Phreatophyte Control - June 1963.

greater errors involved in estimating of evaporation losses and unmeasured depletions, combine to invalidate any calculation of phreatophyte consumptive use by the inventory method.

Ground-Water Studies

The ground-water studies for this report consisted of the collection and interpretation of available data. These data consisted of depth-to-water well readings obtained from the U.S. Geological Survey, Palo Verde Irrigation District, and Bureau of Indian Affairs. Additional depths to water were obtained from the holes used for land inventory.

The ground waters of importance to this report are wholly contained in the flood plain alluvium deposited by the Colorado River and ephemeral streams debauching onto the flood plain area. The alluvial materials appear to be highly permeable and in direct hydraulic continuity with the Colorado River channel. From available data on the depths to water, the ground-water elevation contours were determined for the various study areas. This information was used to determine the direction and gradient of ground-water movement.

The results of these studies indicate that the ground-water movement is generally influent to the river, but that the movement in specific areas can be highly variable, dependent on the geology, topography, recharge from the river, and irrigation water application.

Ground-water conditions in the four areas proposed for clearing and drain construction are as follows:

Yuma Valley Area--The depth to ground water in this area generally ranges from 5 to 10 feet. The dominant hydrologic feature is the ground-water mound caused by irrigation in the Yuma-Mesa Irrigation and Drainage District. The ground water generally moves southwesterly toward Mexico in the southern part of the valley and toward the river channel in the northern part of the valley. In this valley reach the river is effluent.

Cibola Valley Area--The depth to ground water in this valley varies from about 5 to 10 feet. The direction of ground-water movement basically parallels the river channel.

Colorado River Indian Reservation Area--Ground-water depths vary from 10 to 15 feet on most of the nonarable Indian lands. The notable movement is generally parallel to the river in a ground-water trough. Where the reservation lands are irrigated, which roughly encompasses the upper third of the reservation, water is returning to the river. Below this area, the contours indicate that the river is influent.

Fort Mohave Indian Reservation Area--Ground-water depths vary from 10 to 15 feet on most of the nonarable Indian lands. The river in this reach is strongly influent. Studies also indicate that ground water is moving toward Topock Swamp in the lower valley, and in some areas might be moving away from the river beyond the flood plain area.

Land Inventory

An inventory of 229,000 acres, which comprises most of the lands along the Lower Colorado River flood plain between Davis Dam and the International Boundary, was taken for the Lower Colorado River Water Salvage Report - Phreatophyte Control - June 1963. The inventory included all bottom lands on both sides of the Colorado River, except for those lands lying within wildlife refuges, a very small portion of the Colorado River Indian Reservation which is situated on the Arizona side of the river, and all organized irrigation districts. However, federally owned lands within the Palo Verde Irrigation District were included. The classification of lands within the Colorado River Indian Reservation was based on soil series data obtained from the Bureau of Indian Affairs.

The inventory included a general description of the soil and land characteristics found throughout the flood plain area, and a semi-detailed land classification. All six classes of land were mapped: classes 1 to 4, inclusive, were mapped as arable, and 5 and 6 as nonarable. Of the gross acreage studied, 158,000 acres were classified as arable and 71,000 as nonarable. Table 1 shows a summary of the inventory by river reach and landownership.

Phreatophyte Survey

During the spring of 1961, a density survey was made of existing phreatophytes within the study area to determine the extent, density, and species of plants infesting the area. The field procedure used was that which is outlined in "A Guide to the Density Survey of Bottom Land and Streambank Vegetation," by the subcommittee on phreatophytes, Pacific Southwest Inter-Agency Committee, June 1958. The procedures used to arrive at the phreatophyte type and density are presented in detail in the Bureau's Lower Colorado River Water Salvage Report - Phreatophyte Control - June 1963.

The survey showed that phreatophytes infest about 167,000 acres of the 169,000 acres of nonirrigated lands along the Lower Colorado River. The results of the survey are presented in Tables 2 and 3, and the infested areas are shown on Plate 2.

Table 2

Acreage of Types of Phreatophytes by River Reach

Plant	Reach Number								Total
	1	2	3	4	5	6	7 1/	8	
Salt Cedar	1,960	2,050	2,070	11,350	2,940	8,070	0	24,740	53,180
Arrowweed	780	5,260	770	5,500	3,700	23,130	0	11,350	50,490
Mesquite	20	250	0	30	2,380	37,290	0	6,200	46,170
Salt Bush	30	210	0	0	0	780	0	340	1,360
Baccharis	0	0	0	0	0	0	0	0	0
Willow	10	0	0	0	0	0	0	40	50
Carrizo Cane	0	50	0	0	0	0	0	0	50
Tules	0	1,410	3,870	1,370	0	230	0	4,770	11,650
Mixed	360	910	50	90	1,210	1,500	0	140	4,260
Totals	3,160	10,140	6,760	18,340	10,230	71,000	0	47,580	167,210

1/ Phreatophytes negligible--not surveyed. Resort areas and narrow canyons within wildlife refuge.

Table 3

Acreage of all Phreatophytes by
Landownership, River Reach, and State

Reach No.	State	Type of Landownership					Total
		Private	State	Federal	Indian	Wildlife Refuge	
1	Ariz.	1,040	0	2,120	0	0	3,160
2	Ariz.	690	500	3,210	0	0	4,400
	Calif.	550	390	4,800	0	0	5,740
3	Ariz.	0	0	0	0	3,920	3,920
	Calif.	0	0	0	0	2,840	2,840
4	Ariz.	3,060	730	9,800	0	0	13,590
	Calif.	1,890	90	2,770	0	0	4,750
5	Ariz.	560	20	150	9,500	0	10,230
	Calif. 2/	0	0	0	0	0	0
6	Ariz.	0	0	0	62,870	0	62,870
	Calif.	120	0	3,420	4,590	0	8,130
7 1/		0	0	0	0	0	0
8	Ariz.	9,500	0	1,890	16,690	5,390	33,470
	Calif.	1,430	790	570	4,020	2,890	9,700
	Nevada	30	1,860	480	2,040	0	4,410
Totals	Ariz.	14,850	1,250	17,170	89,060	9,310	131,640
	Calif.	3,990	1,270	11,560	8,610	5,730	31,160
	Nevada	30	1,860	480	2,040	0	4,410
Grand Totals		18,870	4,380	29,210	99,710	15,040	167,210

1/ Phreatophytes negligible--not surveyed. Resort areas and narrow canyons within wildlife refuge.

2/ Not included in study area.

PART III. WATER USE AND SALVAGE

Estimates of annual consumptive water use by phreatophytes and of the annual potential water salvage by phreatophyte eradication are presented below.

Annual Water Use by Phreatophytes

The Blaney-Criddle Method was used to estimate the consumptive use rates for the various phreatophytes, and the results were compared with available field test data. The water use quantities presented include only ground-water use, as effective precipitation has been excluded.

The Blaney-Criddle formula gives the consumptive use rate (acre-feet/acres) of plants for a growth at 100 percent volume density; therefore, it was necessary to adjust these maximum use rates for sparser plant growth as determined from random transects. Weighted average annual use rates per acre were derived for various grouping of plants having various cover intercepts and vertical densities.

Using the weighted average use rates, it was estimated that the total annual water use by the 167,000 acres of phreatophytes within the study area amounts to 568,000 acre-feet. Table 4 presents a summary of the estimated annual water use for each phreatophyte type by river reach, and Table 5 presents the estimated annual use of all phreatophytes by type of landownership and river reach.

Water Salvage Factors

In estimating the amount of water that could be salvaged for beneficial uses by eradication and control of phreatophytes, many factors were considered. Consideration was given to the present use by these plants, depths to ground water before and after eradication, continued water use by phreatophytes not subject to eradication, bare-ground evaporation, consumptive use by native regrowth, and salvage effects of proposed and existing drains. Since no field measurements were available of actual quantities of water salvaged by phreatophyte eradication, and the data available for estimates of the above considerations were limited, it was necessary to establish basic criteria in order to evaluate the factors enumerated above. The requirements for realizing any potential water salvage, and development of criteria for evaluating various nonsalvageable losses, are subsequently discussed.

Once the phreatophytes are eradicated their control becomes a problem. Some methods of control include:

Table 4
Annual Water Use of Types of Phreatophytes by River Reach

Quantities in Acre-Feet

Plant	Reach Number								Total
	1	2	3	4	5	6	7 1/	8	
Salt Cedar	4,390	9,730	8,920	50,620	11,570	35,430	0	89,060	209,720
Arrowweed	1,970	17,610	2,840	18,650	14,080	51,360	0	39,820	146,330
Mesquite	30	670	0	80	5,040	69,730	0	15,740	91,290
Saltbush	110	280	0	0	0	1,160	0	1,480	3,030
Baccharis	0	0	0	0	0	0	0	0	0
Willow	40	0	0	0	0	0	0	130	170
Carrizo Cane	0	380	0	0	0	0	0	0	380
Tules	0	11,990	33,260	11,660	0	1,970	0	40,670	99,550
Mixed	1,700	3,800	300	350	6,290	4,430	0	660	17,530
Totals	8,240	44,460	45,320	81,360	36,980	164,080	0	187,560	568,000

1/ Phreatophytes negligible--not surveyed. Resort areas and narrow canyons within wildlife refuge.

Table 5
Annual Water Use of All Phreatophytes by
Landownership, River Reach, and State

Quantities in Acre-Feet

Reach No.	State	Type of Landownership					
		Private	State	Federal	Indian	Wildlife Refuge	Total
1	Arizona	2,910	0	5,330	0	0	8,240
2	Arizona	2,950	1,830	15,950	0	0	20,730
	Calif.	1,980	1,520	20,230	0	0	23,730
3	Arizona	0	0	0	0	26,190	26,190
	Calif.	0	0	0	0	19,130	19,130
4	Arizona	13,260	2,990	42,350	0	0	58,600
	Calif.	9,480	380	12,900	0	0	22,760
5	Arizona	2,140	70	590	34,180	0	36,980
	Calif. 2/	0	0	0	0	0	0
6	Arizona	0	0	0	137,490	0	137,490
	Calif.	280	0	9,770	16,540	0	26,590
7 1/		0	0	0	0	0	0
8	Arizona	32,900	0	6,630	57,950	33,630	131,110
	Calif.	5,000	2,760	2,050	13,200	18,050	41,060
	Nevada	120	6,610	1,710	6,950	0	15,390
Totals	Arizona	54,160	4,890	70,850	229,620	59,820	419,340
	Calif.	16,740	4,660	44,950	29,740	37,180	133,270
	Nevada	120	6,610	1,710	6,950	0	15,390
Grand Totals		71,020	16,160	117,510	266,310	97,000	568,000

1/ Phreatophytes negligible--not surveyed. Resort areas and narrow canyons within wildlife refuge.

2/ Not included in study area.

1. Replacement with beneficial species of plants under good farm management.

2. Maintained recreational areas and parks.

3. Periodic defoliation of plants to reduce transpiration.

4. Continuous control of regrowth in eradicated areas without beneficial redevelopment.

The surveyed phreatophytes included hydrophytes (e.g., tules and carrizo cane) which can be eliminated only by drainage. Some of the hydrophyte-infested areas will be drained by accomplishment of river channelization plans, 1/ and others would be eliminated by construction of drains, and some areas will remain that cannot be economically drained owing to topographic limitations. There is also a significant acreage of phreatophytes within existing wildlife refuges that is not subject to eradication for water salvage.

The annual water salvage programed in this report is that which would accrue under method 4 above from the eradication and control of phreatophytes infesting about 22,000 acres of Federal lands and 20,000 acres of nonarable Indian lands, none of which would be affected by the river channelization plans.

The continuing development of arable private, State, and Indian reservation lands will constitute a replacement of the nonbeneficial phreatophytes with beneficial agriculture plants. The water presently being consumed by the phreatophytes infesting these lands will be adequate for the irrigation of crops. Therefore, this salvaged water will not be available for use in other parts of the area.

It is believed essential that drains be constructed in conjunction with a program of phreatophyte eradication and control. In many areas, clearing these plants will cause the ground water to rise to such an extent that large amounts of water will be lost through evaporation from the bare ground. In addition, a moist soil condition, brought about by shallow depths to water, provides an excellent environment for seed germination and, hence, rapid regrowth of phreatophytes. Therefore, drains are necessary to salvage the increased ground-water storage, and to hold the ground-water table down after eradication of phreatophytes.

1/ Bureau of Reclamation reports: "Reconnaissance Report, Channelization Lower Colorado River," Boulder City, Nevada, March 1962; and "Report on Comprehensive Plan, Colorado River Channelization, Palo Verde and Cibola Valley Divisions," Boulder City, Nevada, December 1959.

The effects on the subsurface water by existing drains and existing and proposed river channels, and by clearing phreatophytes, were evaluated to determine areas with high water tables that would be subject to continued nonsalvageable evapotranspiration losses. These areas were used as the basis for determining a drainage system layout and subsequent water salvage.

Nonsalvageable Water Losses

Evaporation from Bare Soil--From published heights of capillary zones for various soil types and the characteristics of the existing soils within the study area, as determined by the land inventory, it was determined that the opportunity for evaporation from ground water exists in areas where depths to water are generally from 0 to 5 feet. Available data indicate that in areas in which the depth to ground water was greater than 5 feet the loss of ground water would be insignificant, as only low water-using desert xerophytes would exist, and bare-ground evaporation would not occur. Based on field measurements 1/ of evaporation from bare-soil tanks in the area and from comparisons with bare-soil evaporation data from other areas, the average annual evaporation rate from bare land in areas of projected high ground water will be about 0.53 acre-foot per acre. This rate does not include precipitation; therefore, the source for evaporation is from ground water only.

Consumptive Use by Native Regrowth--Several areas in the Southwest have been subjected to programs of phreatophyte eradication, and within these areas there has occurred a regrowth of native grasses and bushes where the ground water, subsequent to eradication, has risen sufficiently to permeate the root zone. These previous experiences indicate that areas on the Colorado River flood plain with depths to water within 3 feet would support a regrowth of native vegetation. The average annual consumptive use by native regrowth that was used for the study area, based on the Blaney-Criddle Method, was 4.60 acre-feet per acre. This water use rate was adjusted to reflect the average regrowth consumptive uses that would occur in regrowth areas owing to varying depths to ground water.

Potential Water Salvage

There are 167,000 acres of phreatophytes within the study area on the Lower Colorado River flood plain. Of this total, 12,000 acres are hydrophytes which can be eradicated by drainage only, 6,000 acres are in wildlife refuges, and 9,000 acres will be eradicated under the river channelization program. Of the 140,000 acres remaining, 98,000 acres are on private, State, and arable Indian reservation lands. These phreatophytes could be cleared incidental to continuing land development, and the present nonbeneficial use of water which has not

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1/ Evapotranspiration station near Yuma, Arizona--studies conducted by U. S. Geological Survey.

been considered salvageable would, by direct conversion, provide an adequate water supply for further land development. The remaining 42,000 acres would be eradicated under this program.

Based on the present consumptive use of water by phreatophytes and an evaluation of the requirements discussed previously in this chapter, the total potential water salvage that would become available by eradication and control of phreatophytes on the 42,000 acres of land would be about 100,000 acre-feet per year. These estimates exclude precipitation: therefore, the 100,000 acre-feet of water represents that which would be salvaged from subsurface flows from the Colorado River for other beneficial uses.

Table 6 presents the areas programed for eradication under the plan of development presented in this report and the derivation of the 100,000 acre-feet of water that would be annually salvaged.

PART IV. PLAN OF DEVELOPMENT

The potential plan of development would clear phreatophytes from and construct open drains on 42,000 acres of Federal and nonarable Indian lands which are located in the four following areas:

Area	
1. Yuma Valley	7,000 acres in reach from Arizona-Mexico Boundary to Imperial Dam
2. Cibola Valley	11,000 acres in reach from below Cibola Lake to Ehrenberg
3. Colorado River Indian Reservation	3,000 acres in reach from Ehrenberg to Parker Dam
4. Ft. Mohave Indian Reservation	21,000 acres in reach from Topock to Davis Dam

Phreatophyte Eradication and Control

A considerable amount of eradication and control work has been done by various agencies in areas throughout the Southwest, using both mechanical and chemical methods. To estimate costs that would be incurred by the proposed program, data were compiled for clearing and control work accomplished by several agencies over the past 20 years. These data included field costs based on force account work and on work performed by contract. All prices were indexed to January 1962.

Based on field results in various areas, the most effective means of phreatophyte eradication appears to be by mechanical

Table 6
Derivation of Potential Water Salvage
Lower Colorado River - Phreatophyte Control
Pacific Southwest Water Plan

Reach Numbers	Location	Total 1/ Phreatophytes in Area		Phreatophytes 2/ NOT Subject to Eradication Under this Program		Phreatophytes Subject to Eradication		Phreatophytes Subject to Regrowth Control		Phreatophyte Consumptive Use on Lands Subject to Eradication		Phreatophyte-Potential Water Salvage	
		Federal (Ac.)	Indian (Ac.)	Federal (Ac.)	Indian (Ac.)	Federal (Ac.)	Non-Arable Indian (Ac.)	Federal (Ac.)	Non-Arable Indian (Ac.)	Federal (Af/Yr.)	Non-Arable Indian (Af/Yr.)	Federal (Af/Yr.)	Non-Arable Indian (Af/Yr.)
1,2	Yuma Valley Area	10,130	-	3,130	-	7,000	-	5,600	-	23,690	-	12,628	-
4	Cibola Valley Area	12,570	-	1,570	-	11,000	-	8,000	-	44,400	-	23,088	-
5,6	Colorado River Indian Res. Area	3,570	76,960	2,270	75,160	1,300	1,800	1,000	1,200	2,995	5,400	1,727	3,942
8	Ft. Mohave Indian Res. Area	2,940	22,750	40	4,750	2,900	18,000	1,000	7,000	9,900	61,380	8,200	50,945
	SUBTOTALS	29,210	99,710	7,010	79,910	22,200	19,800	15,600	8,200	80,985	66,780	45,643	54,887
	TOTALS (Rounded)	129,000		87,000		42,000		24,000		148,000		(101,000) 100,000	

1/ Excludes private and State lands which are subject to continuing agriculture and recreation development.
2/ Includes arable Indian lands subject to continuing irrigation development, areas affected by river channelization and negligible infestations.

clearing. In developing estimates for mechanical clearing, data were used that are representative of the plant types and densities of growth. A weighted average field cost per acre was computed from cost data for clearing acreages, generally larger than a square mile and by force account. The total costs based on mechanical clearing by contract were estimated to be $50 per acre, which includes $5 per acre for engineering and overhead.

Based on work done in other areas, particularly along the Rio Grande River and Pecos River floodways, very effective regrowth control has been accomplished by mechanical means. Excellent results have been obtained by using tractor-mounted undercutting blades every two years or so, and annual mowing with tractor-drawn rotary brush cutters. The annual costs include costs for stacking and burning, and indirect costs of 50± percent of the field costs to cover surveying, supervision, overhead, and depreciation on equipment. The estimated annual cost of regrowth control, also by force account, would be $5 per acre.

Drains

Investigations show that drains, in conjunction with mechanical eradication and control methods, would be the most efficient means for accomplishing the proposed program. The procedures and criteria used to determine drain requirements follow.

Layout--The ground-water reservoir was evaluated for conditions before and after eradication to determine areas that would be susceptible to salvage by open drains. Within these areas, topographic and ground-water gradients were analyzed to permit proper placement and determination of hydraulic gradients of drains. The layout of the drain system was done on 1/24,000 U.S.G.S. quadrangle maps. Drainage was not provided in those areas where the depth to ground water would exceed 5 feet.

Drainage Criteria--The following criteria and procedures were used to determine the acres subject to drainage, spacing of drains, and water salvage:

1. The areas susceptible to drainage, and the spacing of drains, were determined by engineering analyses and judgment in conjunction with available maps and data.

2. The installation of drains in a regrowth area would not eliminate all evapotranspiration and bare-ground evaporation. Owing to terrain and soil characteristics, the reduction of these losses would be 60 percent, all of which could be salvaged with drains.

Designs--All subdrains would have a 3.0-foot-base width and $1\frac{1}{2}$:1 side slopes, and main drains would have 5.0-foot-base widths and $1\frac{1}{2}$:1 side slopes, with average depths of 7 feet and 10 feet, respectively. Both drain sections meet the hydraulic demands of the drained areas. It was determined that approximately 141 miles of drains would be required, with capacities ranging from 2 to 36 cfs.

Regrowth Control with Drains--Based on the anticipated effectiveness of the drains, it was determined that in the areas susceptible to drainage the acreage requiring regrowth control would be reduced 50 percent.

Based on local conditions and January 1962 prices, the average total construction cost for the required drains would be about $11,560 per mile. This includes 30± percent of the field cost for engineering, supervision, and overhead. It is estimated that these drains would require complete cleaning every other year. On this basis, annual operation and maintenance costs were computed to be about $730 per mile, including indirect expenses.

Summary of Costs

Based on unit costs and criteria developed in previous sections of this chapter, the total capital cost would be as follows:

Capital Costs (by contract)	
Phreatophyte Clearing - 42,000 acres @ $50/acre	= $2,100,000
Construction of Drains - 141 miles @ $11,560	= 1,630,000
Total Capital Cost (Clearing and Drains)	$3,730,000

Following the initial period for clearing and construction, the total annual maintenance costs, based on unit costs and criteria developed previously, would be as follows:

Annual Maintenance Costs (by force account)	
Regrowth Control - 24,000 acres @ $5/acre	= $120,000
Maintenance of Drains - 141 miles/year @ $730	= 103,000
Total Annual Maintenance Cost	$223,000

It is estimated that 4 years would be required for completion of initial clearing operations and drain construction. The work schedule is as shown on Control Schedule PF-2, Table 7.

LEGEND: Types of Activity

Preconstruction — Construction

LINE NO	CLASS AND ACCOUNT	PROGRAM ITEM	QUANTITY	UNIT	ESTIMATED TOTAL	TOTAL TO JUNE 30,1965	FISCAL YEARS 1	2	3	4	5			BALANCE TO COMPLETE	ESTIMATED COMPLETION DATE	LINE NO
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1		LOWER COLORADO RIVER WATER SALVAGE--														1
2		PHREATOPHYTE CONTROL	100,000	a.f.												2
3																3
4																4
5		CONSTRUCTION PROGRAM														5
6																6
7	09.32	Clearing Lands:	(42,000)	ac.												7
8		Yuma Valley Area	7,000	ac.	550,000	18,000	10,000	252,000	100,000							8
9		Cibola Valley Area	11,000	ac.	550,000	26,000		200,000	274,000							9
10		Colorado River Indian Reservation Area	3,000	ac.	150,000	8,000			142,000							10
11		Ft. Mohave Indian Reservation Area	21,000	ac.	1,050,000	51,000	250,000	400,000	949,000							11
12																12
13																13
14	09.36	Drain Construction:	(141)	mi.												14
15		Yuma Valley Area	10	mi.	105,000	8,000		10,000	87,000							15
16		Cibola Valley Area	30	mi.	375,000	20,000		10,000	190,000	165,000						16
17		Colorado River Indian Reservation Area	90	mi.	310,000	15,000			42,000	250,000						17
18		Ft. Mohave Indian Reservation Area	11	mi.	840,000	40,000	10,000	230,000	250,000	110,000						18
19																19
20																20
21		TOTAL CONSTRUCTION COST			3,730,000	196,000	270,000	1,072,000	1,477,000	725,000						21
22																22
23		TOTAL PROJECT COST			3,730,000	196,000	270,000	1,072,000	1,477,000	725,000						23
24		Consolidated Expenditures and Credits			-34,000	-34,000										24
25		TOTAL EXPENDITURES			3,696,000	152,000	270,000	1,072,000	1,477,000	725,000						25
26																26
27		TOTAL OBLIGATION			3,696,000	152,000	270,000	1,072,000	1,477,000	725,000						27
28																28
29																29
30																30
31																31
32																32
33																33

Notes:

Recommended: _____ (Operating Office Head) _____ (Date)

Recommended: _____ (Regional Director) _____ (Date)

Recommended: _____ (Chief, Div. of PC & P) _____ (Date)

Approved: _____ (Commissioner) _____ (Date)

Revised: _____ (Date) SHEET ___ OF ___ SHEETS

Form 7-2 — UNITED STATES — AUG. 1961
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

CONTROL SCHEDULE

PACIFIC SOUTHWEST WATER PLAN
LOWER COLORADO RIVER WATER SALVAGE
PHREATOPHYTE CONTROL

Phoenix, Arizona (OFFICE) _____ (DATE) 3 (000000)

☐ GENERAL INVESTIGATIONS ☐ LOAN PROGRAM ■ CONSTRUCTION ☐ OTHER

GPO 940874

TABLE 7

PART V. ECONOMIC ANALYSIS

For the purposes of benefit evaluation and for benefit-cost comparisons, it was assumed that the salvaged water would be used for supplemental irrigation purposes. Many of the areas that could used the salvaged water are presently devoted to the production of general crops which include cotton, barley, sorghum, lettuce, melons, and alfalfa. Many specialty crops are also grown, but the acreage devoted to these crops usually constitutes less than 10 percent of the total cropped area. Farm budgets typical of the service areas of the Pacific Southwest Water Plan indicate that the salvaged water would have an irrigation benefit of about $40 per acre-foot. This value is representative of water delivered to the farm. It was assumed that the water would be conveyed by existing facilities; therefore, the cost of distribution systems would not be involved. Obviously, delivery losses would occur between the point of salvage and the farms, and for this study a delivery loss of 20 percent has been assumed. Under these conditions, the benefits from the water salvage and drainage program presented in this study would be as follows:

100,000 acre-feet x .80 x $40	$3,200,000

Costs associated with the necessary work to obtain the estimated water salvage have been enumerated in preceding sections of the report. The derivation of the annual equivalent values of these costs over a 100-year period of analysis at 3 percent interest, including interest during clearing and construction, is as follows:

Clearing and Drain Construction Cost	$3,544,000 1/
Interest During Construction	186,000
Total Construction Cost	3,730,000
Annual Equivalent Cost (3 Percent)	118,000
Annual Regrowth Control and Maintenance Cost	223,000
Total Annual Cost	341,000
Annual Benefits	$3,200,000
Benefit-Cost Ratio	9.38 to 1.00

1/ Excludes investigation costs - $186,000.

As demonstrated by the benefit-cost ratios, a project to salvage this water now being nonbeneficially used is highly feasible.

UNITED STATES
DEPARTMENT OF THE INTERIOR

PACIFIC SOUTHWEST WATER PLAN

SUPPLEMENTAL INFORMATION REPORT

ON

WATER SALVAGE PROJECTS

LOWER COLORADO RIVER

JANUARY 1964

Interior-Reclamation
Boulder City, Nevada

PACIFIC SOUTHWEST WATER PLAN

Lower Colorado River
Supplemental Information on
Water Salvage Projects

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